Global Scale Intercomparisons of SWE and SCF products

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CANSISE
CANADIAN SEA ICE AND SNOW EVOLUTION NETWORK

esa
European Space Agency

snow
cci

FMI

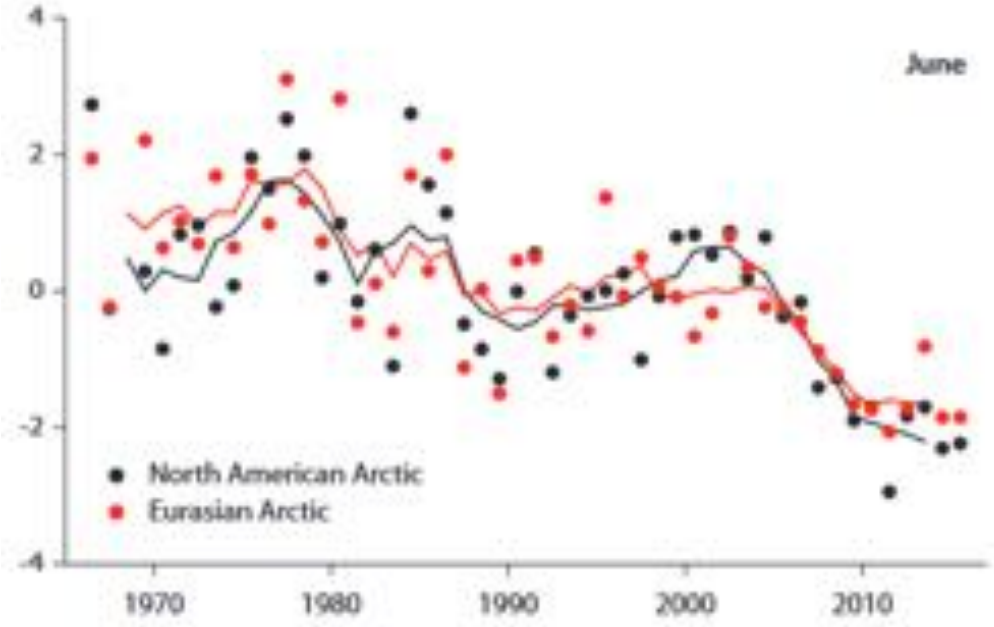
Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

What do we use global scale SWE and SCF for?

- Robust trends in Arctic snow cover with quantitative uncertainty estimates are required to support climate, hydrology, and ecosystem applications

- Support for regular to semi-regular monitoring and assessment activities e.g., Arctic Report Card, SWIPA, SROCC



SWIPA2017

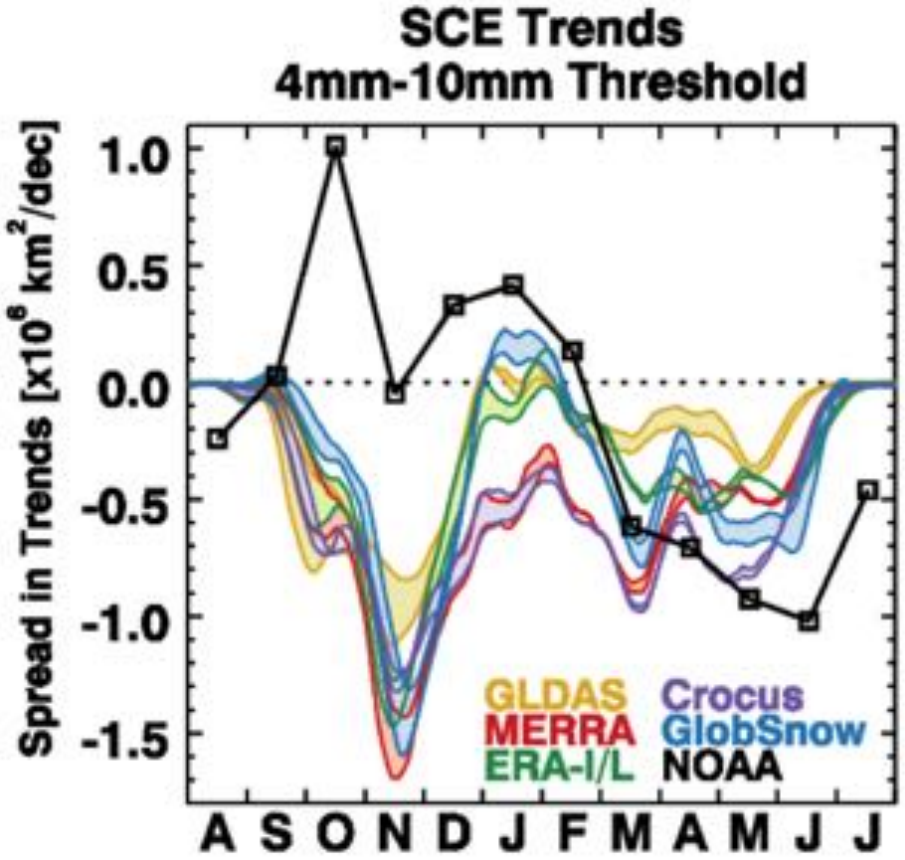
Scientific Strategy

- We don't have 'ground truth' for hemispheric SWE as we might for a variable like air temperature because of the relative sparseness of surface measurements and a lack of representativeness of point snow measurements compared to the spatial heterogeneity

- Rather than trying to identify a single 'best' observational dataset, we work under the assumption that a given data set will perform better in some locations than in others and that averaging multiple data sets will reduce uncorrelated errors.

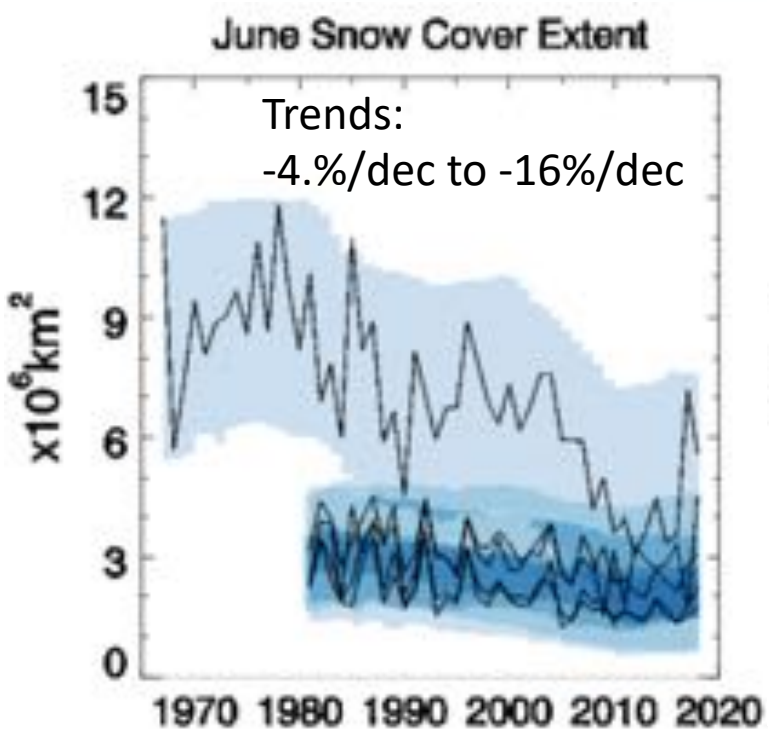
- For this purpose we need multiple examples of SWE analyses from disparate classes

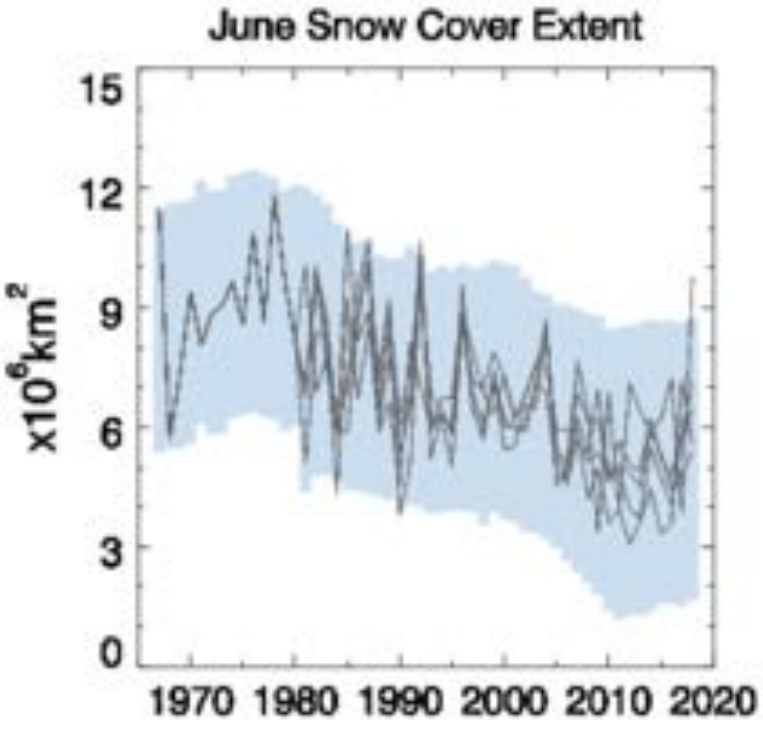
Rational for multi-dataset approach: Outlier Detection

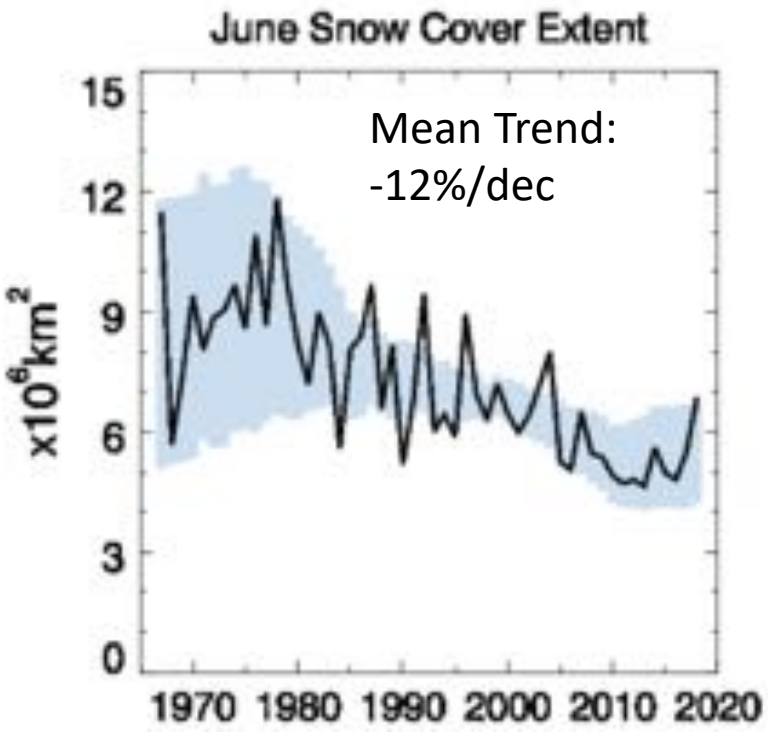


- Reasonable range of agreement among SCE trends from reanalysis and GlobSnow
- Stronger snow loss during the fall and spring than mid-winter
- NOAA CDR shows somewhat stronger trends during the spring very different trends during October and November

Rational for multi-dataset approach: Increased confidence from multiple estimates

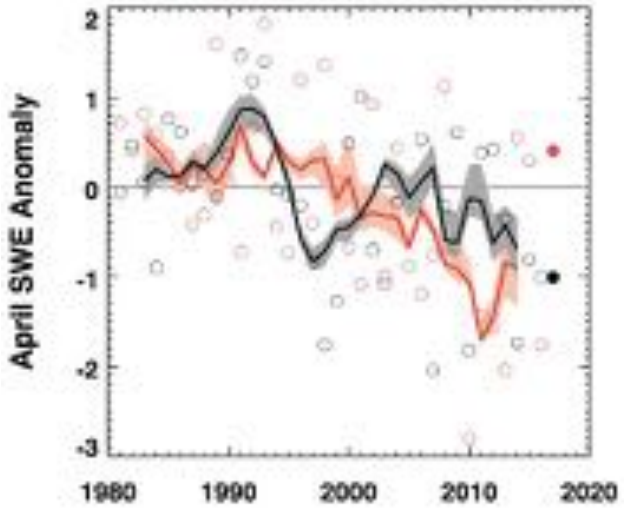






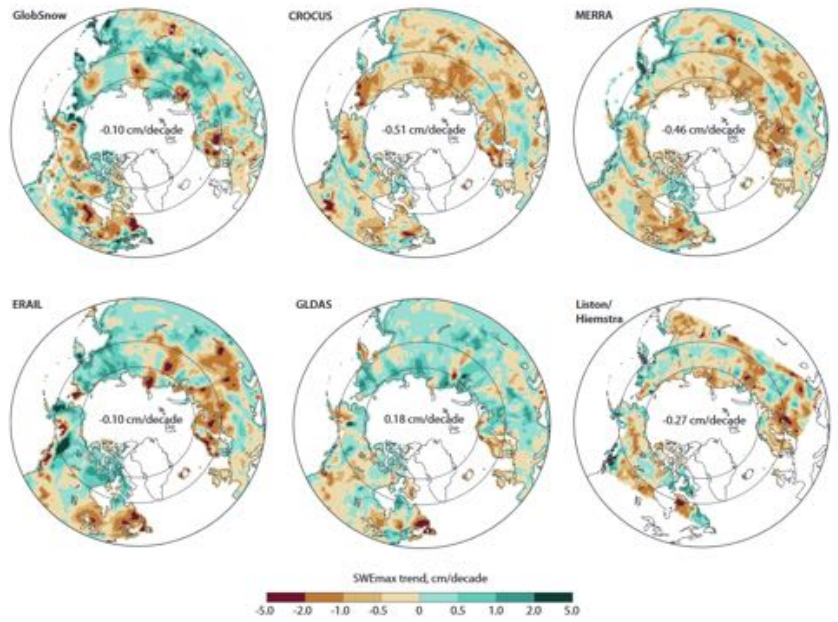
Global Scale SWE Trends from Snow Analyses

Derksen et al. (2017)



Mean April SWE anomalies for Arctic land areas calculated from four independent products for North American (black) and Eurasian (red) sectors of the Arctic.

Brown et al. (2017)



SWE trends, 1981-2010 for 6 independent datasets

- Multi-year average of continental scale SWE anomalies are consistent (left) but spatial variability/inconsistency in trends between products is pronounced (right)
- SCE trends are primarily controlled by temperature and dominated by changes in the marginal snow cover zone for a given season
- SWE trends are affected by variability in both temperature and precipitation and the influence of either driver can accumulate or interfere over the course of the season

Selection of SCF and SWE products

Optical Imagery

- JASMES
- CCI+
- Rutgers/NOAA CDR

- Ideally we would want to use several different classes of snow analyses with as many samples from each class as possible

Passive Microwave

- NASA historical
- NASA standard
- GlobSnow → CCI+

Reanalysis-Based

- MERRA
- MERRA2
- ERA-Interim/Land
- GLDAS-2
- Crocus
- Brown

ESA Snow CCI+ (2018-2021)

Towards multiple EO SCF/SWE products

Snow CCI+ SCF

- Long term well-calibrated record of NH SCF

⟶ Ensemble of SCF products

Snow CCI+ SWE

- Improved PM emission model for forest vegetation; account for subgrid scale lakes
- Increased spatial resolution based on enhanced resolution Tb
- Spatially and seasonally varying snow density
- Influence of continuity of weather station data on trends

⟶ Ensemble of SWE products

Main Objectives of snow_cci:

- **Generation of homogeneous, well calibrated, long-term time series of key snow cover parameters (snow area extent and snow mass) from multi-sensor satellite data for climate applications.**

Intercomparison of Simulated SWE Estimates (reanalysis, LSMs)

CanSISE Ensemble

- ensemble of opportunity
- coarse resolution (~ 50-100km)
- NH domain
- 1981-2010

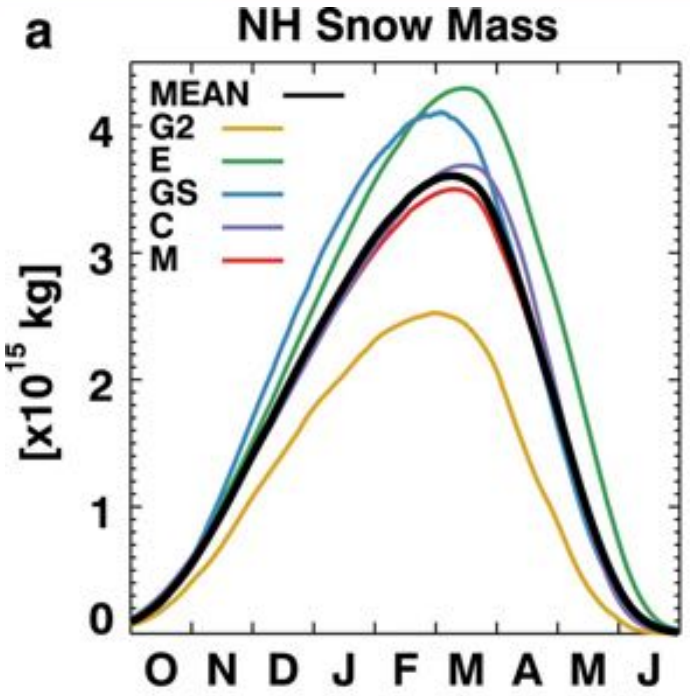
- MERRA
- ERA-Interim/Land
- Crocus/ISBA (ERA-I driven)
- GLDAS2

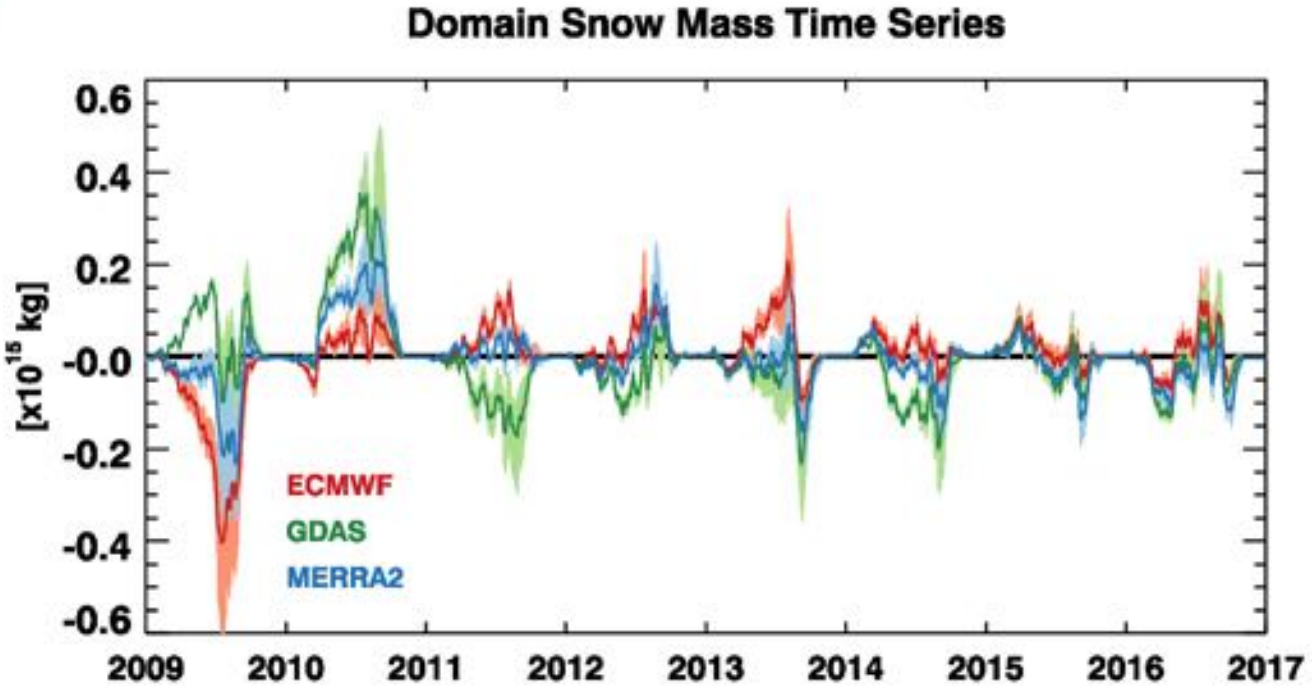
SEUP

- LIS generated ensemble
- 4 LSMs driven by 3 forcings
- high resolution (5km)
- NA domain
- 2010-2017

- CLSMF2.5
- Noah 2.71
- JULES
- Noah-MP

Intercomparison of Reanalysis, LSM and PM SWE Estimates

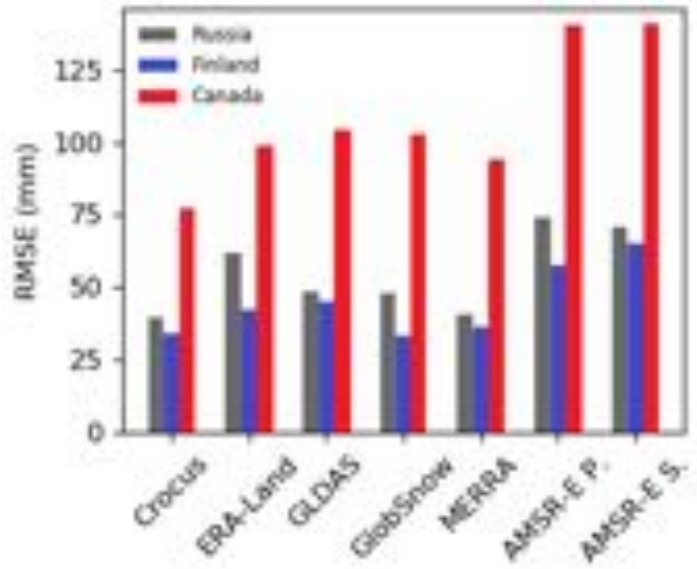




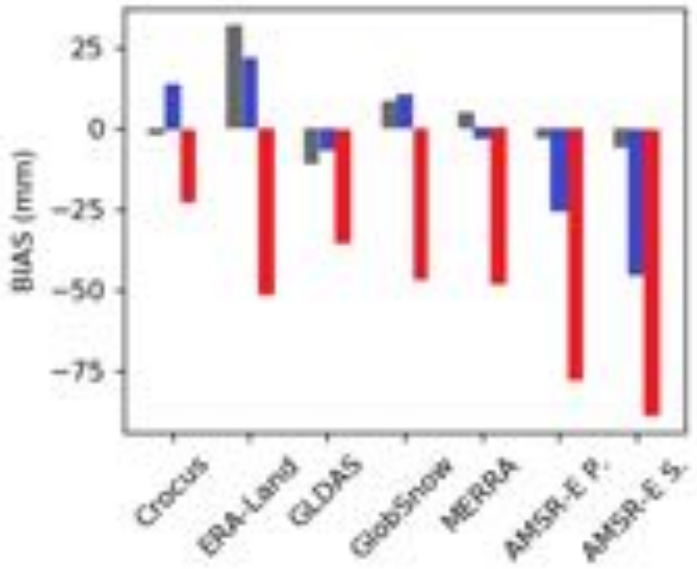
- Large range of estimated climatological snow mass
- Short term anomalies evolve coherently depending on correlation among meteorological forcings
- Longer term seasonal evolution likely to be driven by other factors
- Among LSMs, choice of model contributes more spread than forcing

How do Passive Microwave Products Compare?

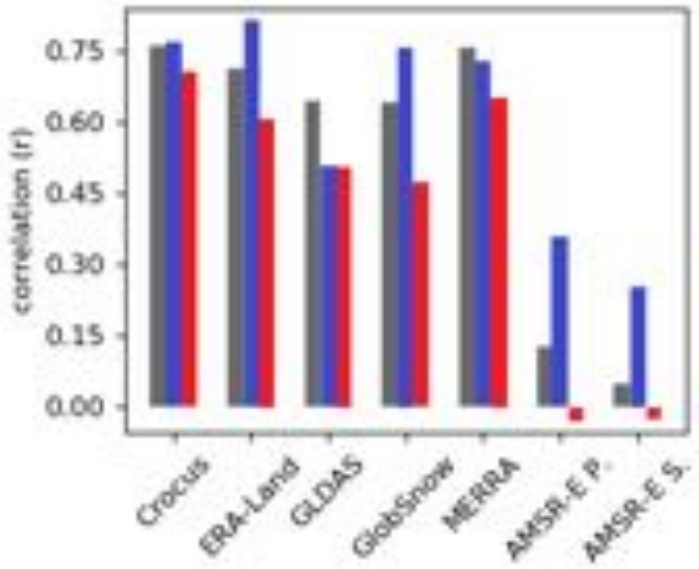
RMSE



Bias

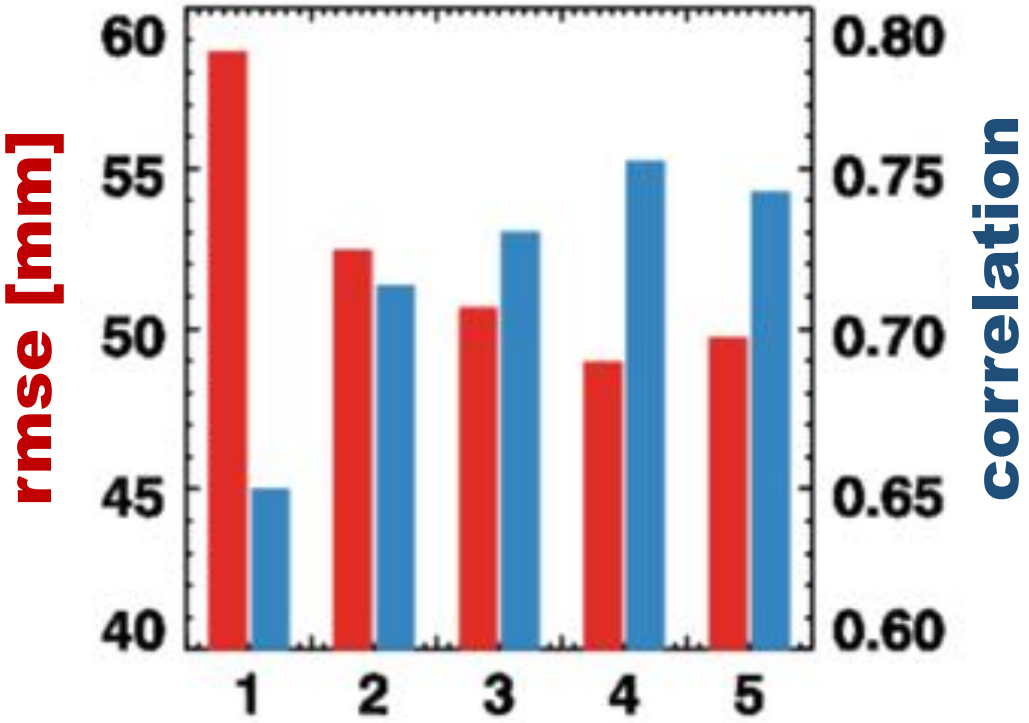


Correlation



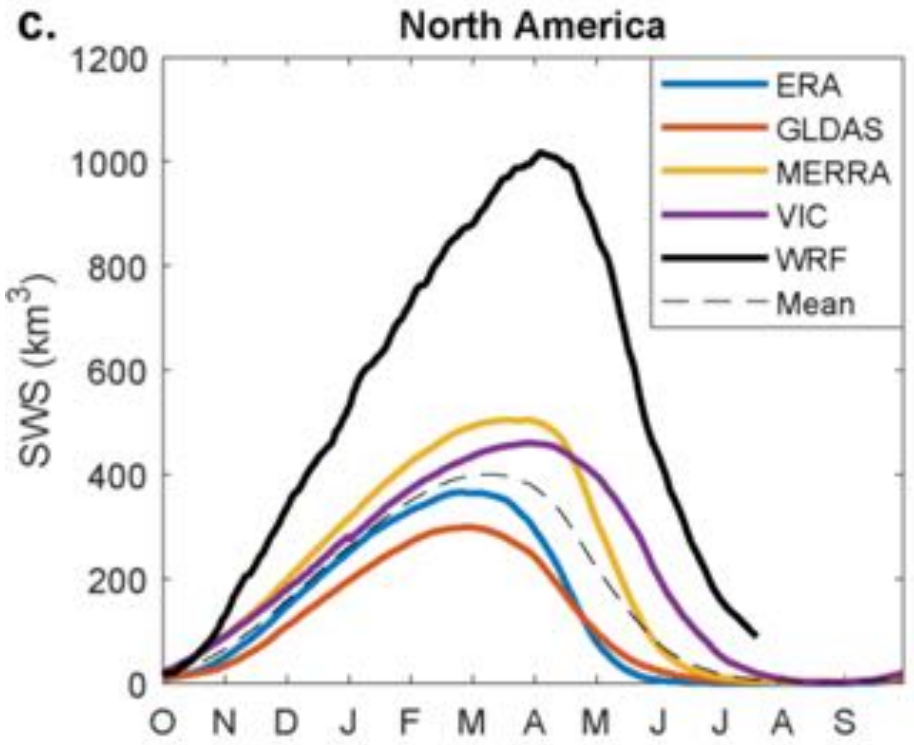
- Snow courses over Russia, Finland, and Canada
- Results are worse for all statistics over Canada
- GlobSnow has comparable rmse, bias, and correlation to model based results
- AMSR-based analyses are substantially worse.

Averaging products improves accuracy

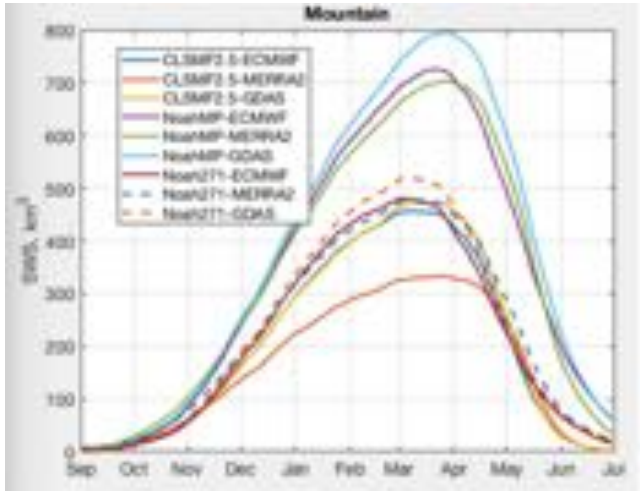


- Averaging additional products decreses rmse and increase correlation with validation data
- All blended products show better correlation with snow course measurements
- Roughly half of products show lower RMSE than the best individual product.

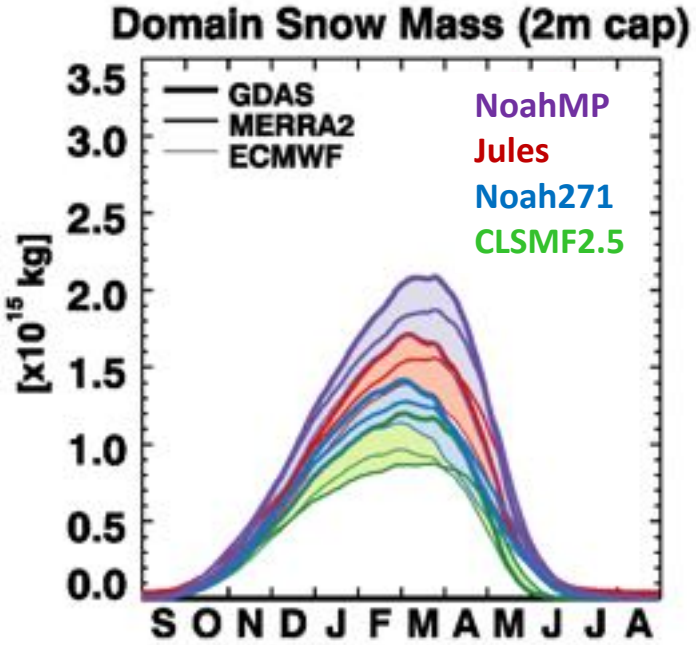
Climatological alpine SWE is even more uncertain

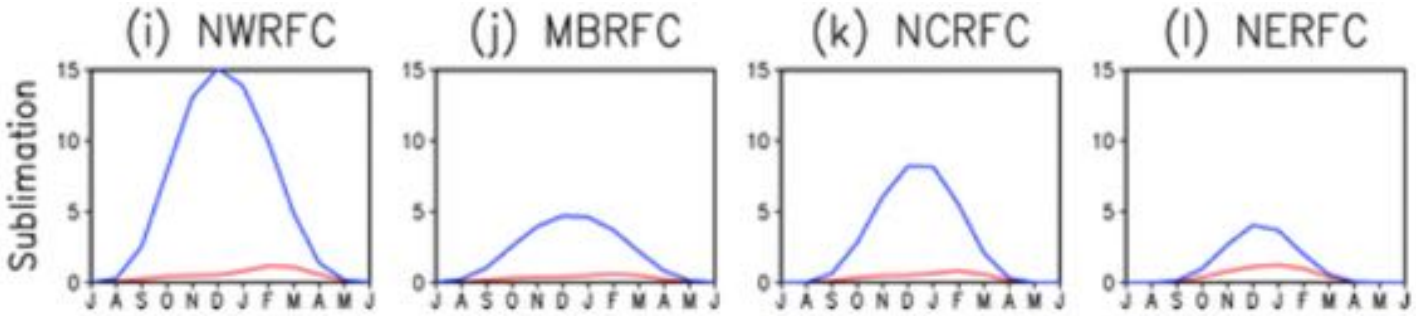


- It isn't clear that differences in alpine water storage are directly tied to model resolution



Poor constraints on sublimation





CLSMF2.5
NoahMP

Xia et al., 2017 demonstrated that sublimation in CLSMF2.5 is an order of magnitude larger than in NoahMP over several regions of the US.

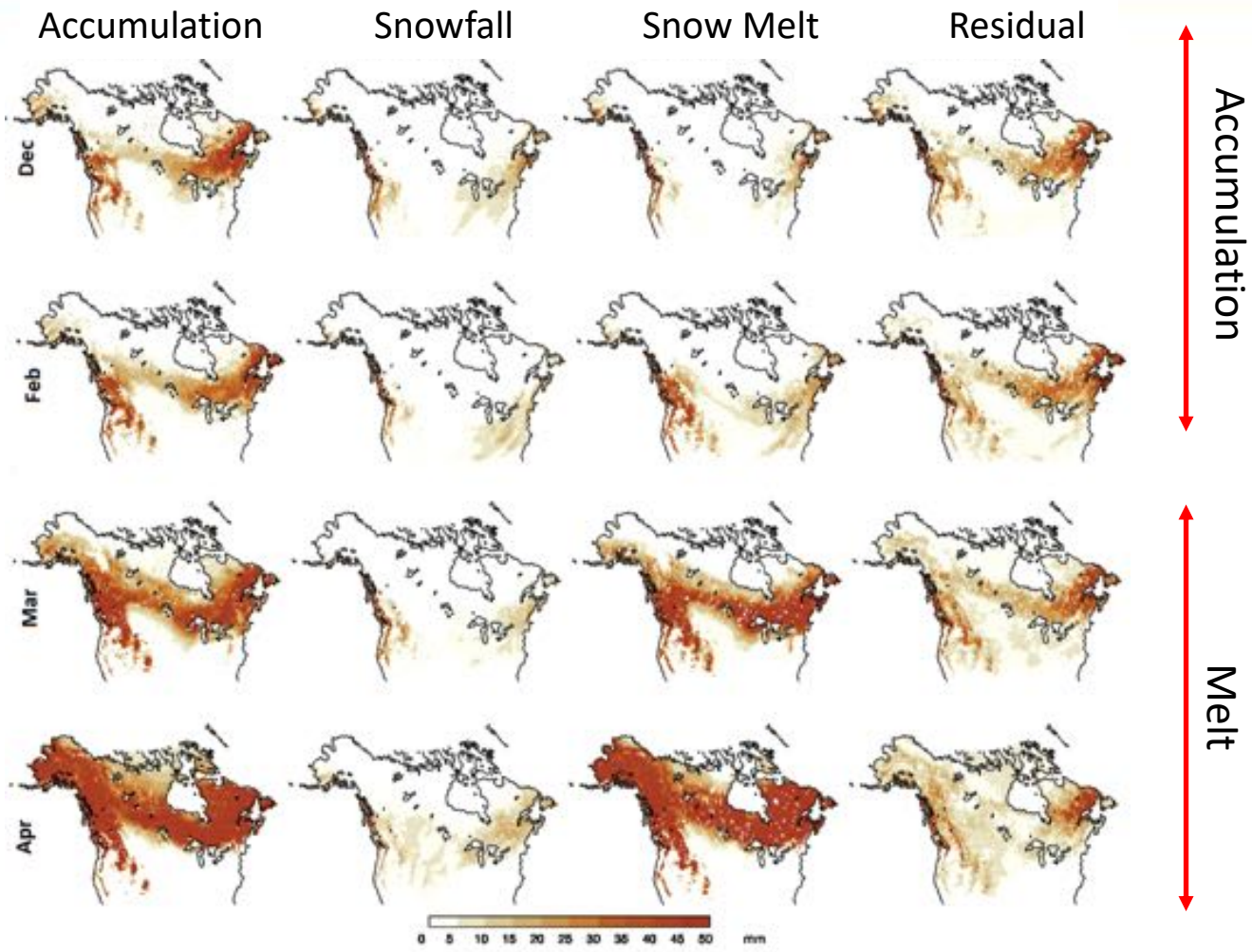
Poor constraints on sublimation

$$\Delta SWE = Ps - M - Ri$$

- During the accumulation period, differences in residual model processes are the dominant source of spread among the SEUP models (rather than rain/snow partitioning or snow melt) .

- Some of this residual spread represents sublimation processes. How much represents other parametrizations? Do the importance of these processes depend on scale?

Spread in:

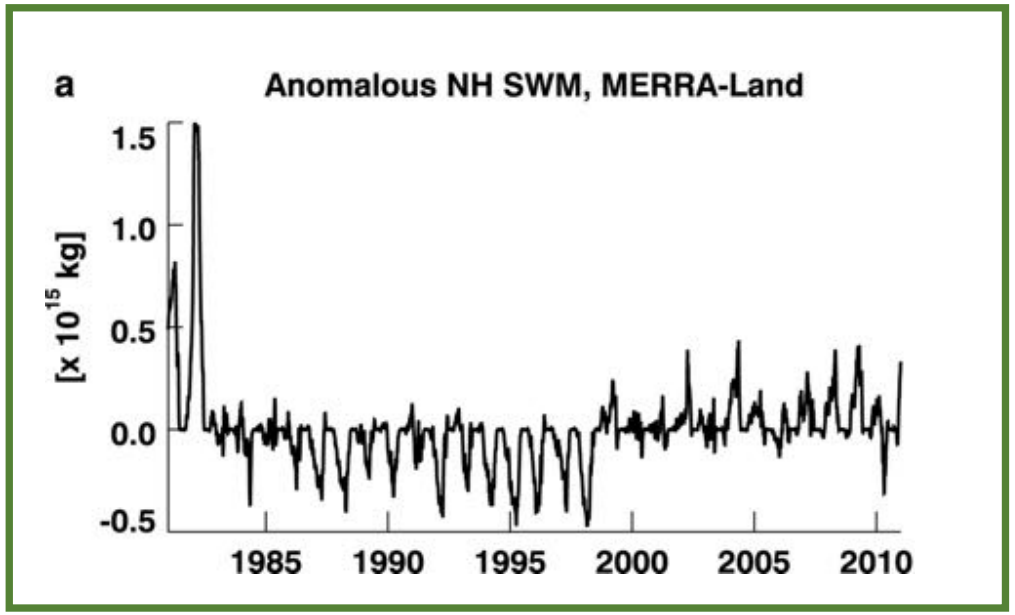


Conclusions

- Gaps: global scale alpine SWE is poorly constrained
- Gaps: A reasonable portion of SWE uncertainty, particularly across the boreal regions of North America seems to be related to differences in sublimation
- Combined use of observations, modeling and remote sensing may be essential for accurate global-scale SWE estimation
- Much of the uncertainty from reanalysis/LSM is related to model structure and parametrization rather than forcing uncertainty: does this result depend on scale?
- Combing multiple products appears to increase accuracy, increases our confidence in variability and climate trends and provides a baseline for comparison with ESM

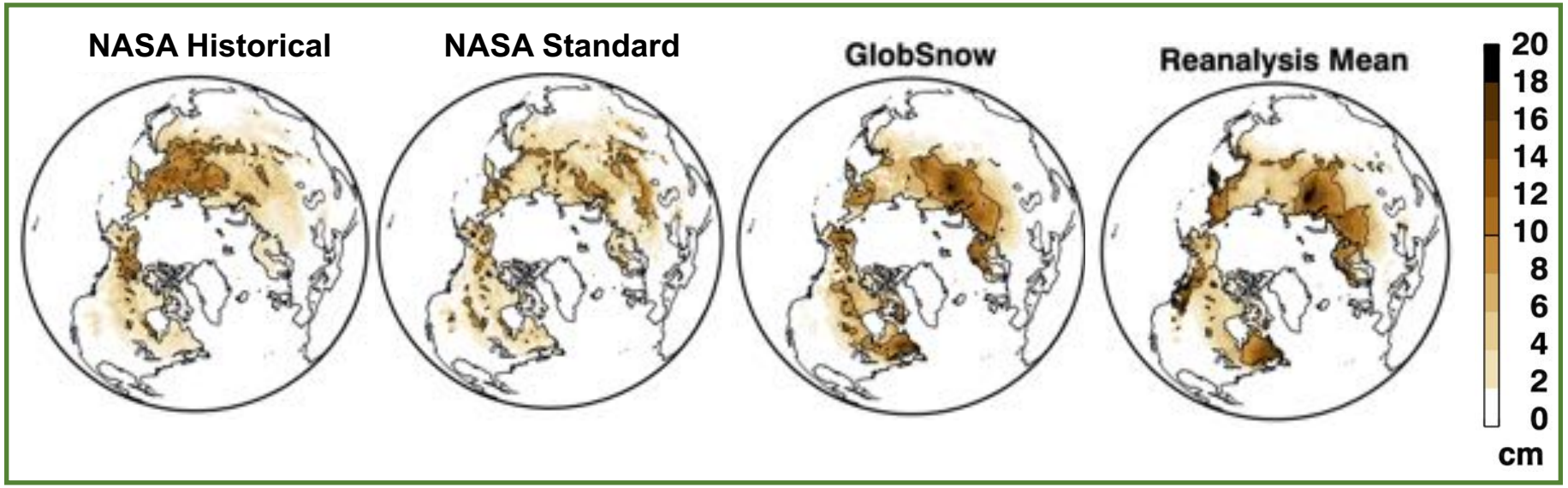
Additional Slides

Temporally homogenous forcing data is required



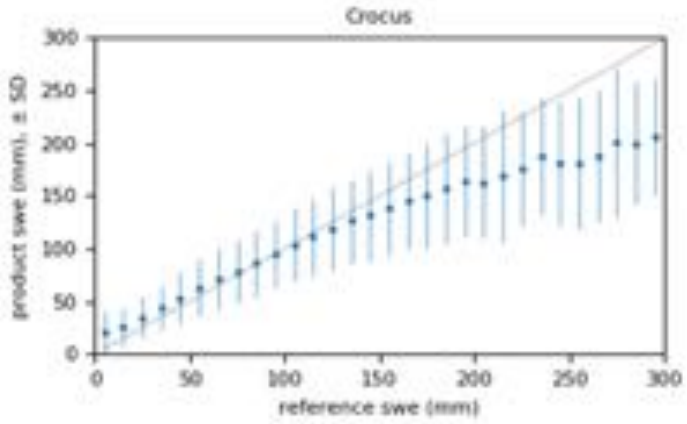
- Because evolution of SWE spatial patterns is controlled by meteorological forcing, abrupt changes to that forcing can lead to spurious trends
- To obtain realistic trend estimates we omit these data sets

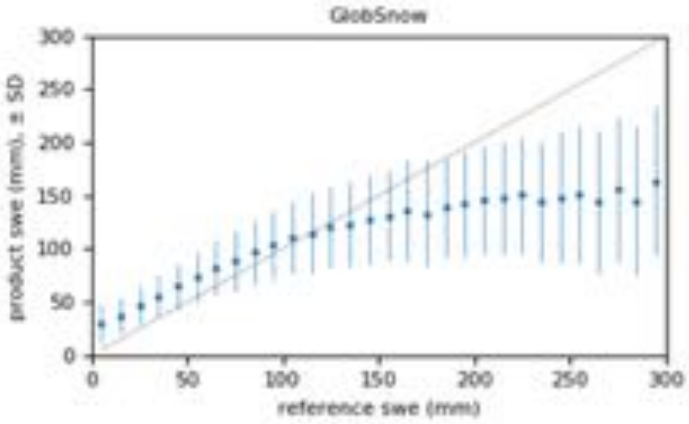
Why do we only consider one PM product?

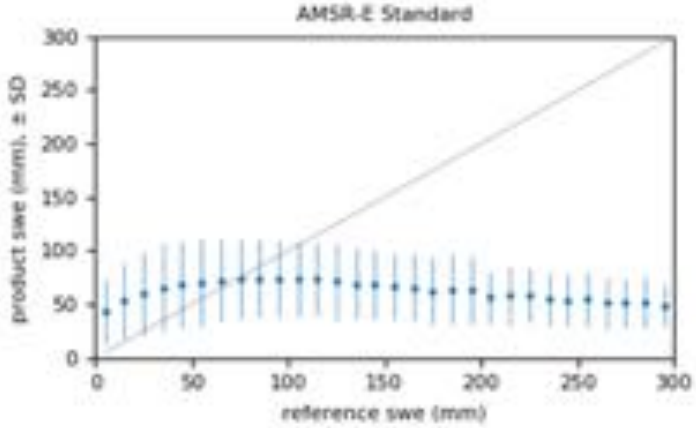


- Comparison with transects over Canada, Finland and Russia indicates that stand alone PM products are not accurate

Validation in SnowPEx and CCI+



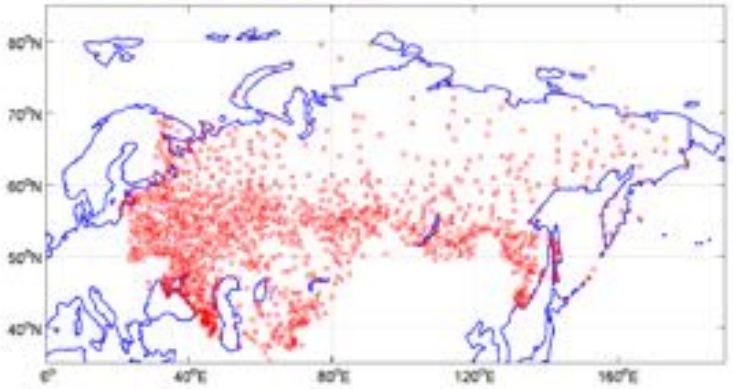




- Snow courses over Russia

Reference Data: snow courses and transects

Russia: 1346 transects, 1-2km long



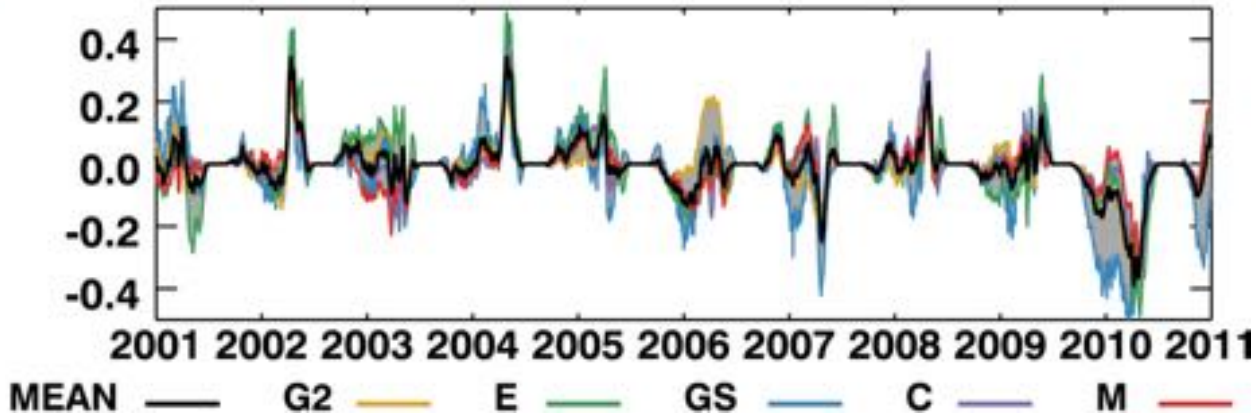
Finland: 100+ snow courses, 4km long

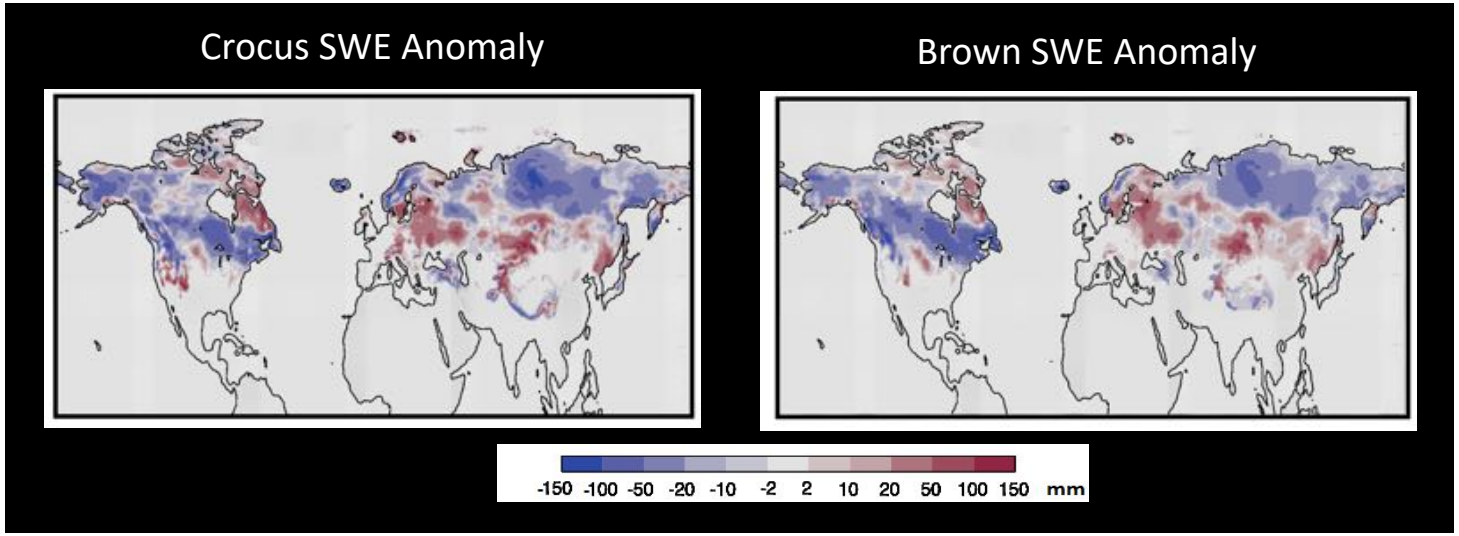
Canada: snow courses, 100-200m long

- Data from broad expanse of Northern Hemisphere territory representing diverse geographical conditions and snow environments
- Restriction to snow courses and transects means we will have better representation of SWE on the scale of PM footprint and reanalysis grid cell
- Direct comparison matching up SWE estimates from the products for grid cells with coincident reference data. This takes advantage of the large number of reference data samples (e.g. 38,000 over Russia over the 2002-2011 period)

What do we use global scale SWE and SCF for?

- Hemispheric/continental time series of integrated snow mass: climatologies, anomalies and trends





Spatial maps of SWE